A Multiple Group Repeated Measures Confirmatory Factor Analysis (CFA) Examination of the Evolutionary Attitudes and Literacy Survey (EALS) Among College Samples

By

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Abstract

The present study examined changes in university students' attitudes toward and knowledge of evolution measured by the previously validated Evolutionary Attitudes and Literacy Survey (EALS). Students were assessed at a large Midwestern U. S. university prior to and following completion of either an undergraduate political science, biology, or evolutionary psychology course. A multiple group repeated measures confirmatory factor analysis (CFA) was conducted to examine latent mean differences in self-reported political activity, religious conservatism, evolution knowledge/relevance, creationist reasoning, evolutionary misconceptions, and exposure to evolution. A significant and notable increase in evolution knowledge/relevance, as well as decrease in creationist reasoning and evolutionary misconceptions was observed for the evolutionary psychology course. In contrast, no significant change in evolution knowledge/relevance was observed for the biology course. The implications of these findings, as well as limitations and future research for evolution education are discussed.

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Part I: Introduction

Evolution and Science Education

Now over 150 years old, Charles Darwin's *On the Origin of Species* and his accompanying theory of evolution still face substantial criticism and denial from individuals across the western world, but in particular the United States. The U.S. is ranked second to last, only surpassing Turkey, in an examination of 34 prominent countries across the world for public acceptance of evolution (Miller, Scott, & Okamoto, 2006). Moreover, between 1985 and 2005 the American public's acceptance of evolution has decreased from 45% to 40% (Miller et al., 2006) and a recent Gallup study reported that 44% of Americans found the creationist view "God created man as is 10,000 years ago" closest to their view on human origins (Newport, 2008).

Evolution faces opposition from a variety of sources, and common critics include individuals from young-earth creationism (Segraves, 1977; Whitcomb & Morris, 1961) and intelligent design (Meyer, 1999), whom claim, a host of moral and social objections to evolutionary theory among many other reasons. Many of these criticisms appear to be influenced by religion (Scott, 2004), low exposure to evolution (Clores & Limjap, 2006; Lambrozo, Thanukos & Weisberg, 2008), and political ideologies (Patterson & Rossow, 1999), as well as a lack of scientific understanding, genetic literacy, and evolutionary knowledge. Driven by these objections, opponents to Darwin's theory have persistently argued against evolution education throughout the 20th century from historical *The State of Tennessee v. Scopes* trial to the more recent "Kansas Evolution Hearings" in 2005.

Opposition to evolution and the subsequent judicial hearings have also had an effect in the classroom. The topic of evolution in high school classrooms is highly avoided by teachers and receives only a small percentage of instructional time during the school year (Rutledge & Mitchell, 2002) even though both the National Association of Biology Teachers (NABT) and the National Science Education Standards (NSES) view evolutionary theory as fundamental to middle and high school science education (Evans, 2005). In fact, a recent national study of nearly a thousand high school biology teachers revealed that the majority of teachers (60%) were cautious in either advocating evolutionary biology or creationism, and only a third of these surveyed instructors were presenting evolutionary theory in concordance with national recommendations (Berkman & Plutzer, 2011). These prevalent negative attitudes toward evolution throughout America have prompted many researchers and science educators to become increasingly interested in exploring and changing students' attitudes toward evolution.

Evolution education appears to be a growing research area in several journals (e.g., *Journal of Research in Science Teaching*, *Science Education*, *The American Biology Teacher*, *Evolution: Education and Outreach*), and topic of conversation among professional organizations (e.g., NABT, NSES). For example, Gregory (2009) lists over 40 publications since 1975 examining evolutionary misconceptions among a variety of student populations, with half of these examinations occurring within the past decade. Additionally, strong concern for evolution education has even lead educators to the develop courses purposely designed to increase both favorable attitudes toward and knowledge of evolution (O'Brien, Wilson, & Hawley, 2009; Wilson, 2005).

Previous Courses Examined

The curricular effectiveness and attitudinal change from evolution education has been examined in a variety of scholastic settings. Studies of high school biology courses in the United States have revealed that upon completing a course in biology, 37% of students comprehended concepts such as genetic variance, but incorrect Lamarckian and teleological explanations were still endorsed by 20% of students (Settlage, 1994). Likewise, Wallin, Hagman, and Olander (2001) reported that the majority of a small sample of secondary education Swedish students demonstrated increased knowledge of genetic variation and mutation both immediately after and a year following completion of a biology course. Among high school biology teachers, the instructor's knowledge of evolution is one of the most important predictors of evolution instruction (Aguillard, 1999). Yet with some concern, Osif (1997) reported that both high school biology and English instructors held similar views on the importance of evolution education with only two-thirds of the respondents claiming evolutionary theory was essential to biological education. Thus, increased biological education (e.g., a biology degree versus an English degree) did not appear to influence a teacher's attitudes toward evolution education. These results are further supported by Nehm, Kim, and Sheppard (2009) whose comparisons of high school biology teachers to non-science high school teachers from the state of New York, revealed that the teachers did not differ in the attitudes toward evolution. Nearly half of the teachers in each group supported instructional time devoted to creationism.

At the university level, examinations of evolutionary knowledge have largely been among samples of biology majors, non-biology majors, and instructors. For biology majors, knowledge about evolution has been shown to increase among first-year students after a semester of introductory biology taught with an active-learning teaching style, but misconceptions about evolution remained for 70% of the students (Nehm & Reilly, 2007). Johnson and Peeples (1987) reported significant increases in understanding science from freshmen to senior undergraduate biology majors, but student attitudes toward evolution remained largely neutral. Whereas Ingram and Nelson (2006) did find increases in attitudes toward evolution in senior biology majors following a course on evolutionary theory, the overall effect size was small.

Bishop and Anderson (1990) reported that undergraduates who were not biology majors demonstrated increases in evolutionary knowledge after completing a biology course with specific curriculum directed toward evolution, but again these students maintained common evolutionary misconceptions, including Lamarckian and teleological explanations. When biology majors are compared to their non-biology major peers, biology majors demonstrate significantly higher evolutionary knowledge (Grose & Simpson, 1982; Johnson, & Peeples. 1987; Alters & Nelson, 2002), but these effect sizes are small. Fortunately, graduate students from a variety of sciences, including engineering, medicine, computer science, biology, and physics report high levels of acceptance and understanding of evolution (Gregory & Ellis, 2009). If increased evolutionary knowledge was demonstrated only for biology majors, then one could suspect the significant findings of past research were largely due to sampling biases. However, these significant increases in evolutionary knowledge for both biology and non-biology-majors demonstrate that the effect is not simply due to student's self-interest in science education, but may also be linked to the biological curriculum the students are exposed to. Unfortunately, thus far these curricula have not successfully eliminated student's misconceptions about evolution.

Perhaps the most promising increases in evolution understanding and acceptance results from Wilson's (2005) newly designed undergraduate curriculum entitled "Evolution for Everyone" that is an active pursuit toward increasing knowledge and acceptance of evolution by demonstrating the theory's relevance and application across both the sciences and humanities. The curriculum in "Evolution for Everyone" differs from previously examined biology courses in that evolutionary theory is linked to human behavior and affairs. Additionally, students were divided into smaller workgroups where they participated in weekly discussions to further facilitate learning outside of the large lecture class. Upon completing this course, a diverse sample of undergraduate majors demonstrated both increased factual understanding and relevance of evolutionary theory (O'Brien et al., 2009). However, an important caveat to these encouraging results was that the course was not required for any major, and therefore may have been a biased sample containing only students self-interested in evolutionary theory.

Previous Measures of Curricular Effectiveness and Attitudinal Change

Many of the aforementioned examinations of curricular effectiveness and attitudinal change in evolution education each employed a different measure to examine change. Furthermore, several of these unique measures were developed solely for a specific empirical study. This assortment of measures in the evolution education literature makes comparisons between studies difficult and the overall view of science education's curricular effectiveness murky. For example, the Views on Science-Technology–Society scale (VOSTS; Aikenhead & Ryan, 1992) largely measures scientific knowledge in a multiple choice format, but was generated on a Canadian high school sample. Thus, it lacks generalizablity to American college students. In addition, the Changes in Attitude about the Relevance of Science scale (CARS; Siegel & Ranney, 2003) measures the relevance of science in general, but does not specifically measure the relevance of evolution. The Conceptual Inventory of Natural Selection (CINS; Anderson, Fisher, & Norman, 2002) consists of 20 multiple choice questions pertaining only to evolutionary knowledge. Lastly, the Measure of Acceptance of the Theory of Evolution (MATE;

Rutledge & Warden, 1999) assesses creationist beliefs, evolutionary knowledge, and understanding of scientific theory. Therefore, the MATE is a closer measure to evolutionary attitudes and literacy.

These aforementioned measures are specific to only certain aspects of attitudes toward and literacy about evolution and do not encompass all potential components. In fact, Nehm and Schonfeld (2008) measured knowledge of natural selection among biology majors with the essay test (Bishop & Anderson, 1990) and the CINS (Anderson et al., 2002) and concluded that these measures were only useful after alterations were made. Nehm and Schonfeld (2008) proposed the need for a better measure of evolutionary knowledge. Similarly, Ingram and Nelson (2006) opted for an unpublished measure of evolution knowledge and attitudes claiming they "were unaware of a suitable instrument that assessed students' attitudes toward evolution, including acceptance of evolution, and the nature of scientific knowledge" (p. 11). A measure that assesses each of these important factors regarding evolution was needed in order to fully examine attitudes toward and knowledge of evolution.

Evolutionary Attitudes and Literacy Survey.

Hawley and Parkinson (2008) were interested in empirically examining evolutionary attitudes, and they developed a variety of scale items to measure not only political and spiritual leanings, but also knowledge of evolution, distrust of the scientific enterprise, and attitudes toward and objections against evolutionary theory. The Evolutionary Attitudes and Literacy Survey (EALS; Hawley, Little, Sunderland, & Mendoza, 2009) is a multidimensional scale that consists of 16 lower order and 6 higher order constructs developed to measure the wide array of factors that influence both an individual's endorsement of and objection to evolutionary theory. The construct and predictive validity of the EALS has been demonstrated by a confirmatory factor analysis (CFA), and structural equation models (SEM; Hawley Short, McCune, Osman, & Little, 2011), respectively. This appropriately validated measure can potentially improve empirical examinations of the effectiveness of evolution education and attitudinal change, especially in conjunction with modern statistical methods.

Methods for Examining Curricular Effectiveness and Attitudinal Change

Traditional Experimental Methods.

Many of the previous examinations of student's evolution acceptance and understanding were pre-test post-test designs and the measurements occurred before and after completion of a course (Grose & Simpson, 1982; Ingram & Nelson, 2006; Johnson & Peeples, 1987; O'Brien, et al., 2009). To test hypotheses of time and group differences, an Analysis of Variance (ANOVA) was conducted, but the ANOVA (i.e., manifest variable) approach contains many assumptions that may be difficult to meet such as, the dependent variable was measured without error (Bagozzi, 1977), homogeneity of variances, and normality. Although a variety of ANOVA alternatives (i.e., Kruskal-Wallis, Welch, and Browne-Forsythe tests), attempt to correct for violations of the latter assumptions (see Lix, Keselman, & Keselman, 1996), examinations of longitudinal and group differences may be better suited for more modern latent variable methods (Fan & Hancock, 2011).

Modern Latent Variable Methods.

Unlike repeated measures ANOVA, latent variable techniques, such as CFA within SEM, allow the researcher to specify a model of an unobserved latent construct (e.g., evolutionary knowledge) that consists of the shared variances of several manifest variables (e.g., survey items). First, the structure of a latent construct measured at multiple time points (e.g., pre-course and post-course) can be examined to determine if change is an effect of time or merely a change in properties of the construct (Brown, 2006). Also, these techniques can account for measurement error, thus creating a more appropriate test of latent means rather than observed means (Thompson & Green, 2006). Latent means can be constrained to equality across groups and/or time, and a chi-square difference test between the constrained means model and a model with freely estimated means can be used to test for hypothesized differences. Therefore, the equality test of latent means can investigate the same hypotheses typically evaluated by the ANOVA framework, while making less assumptions (see Fan & Hancock, 2011; Hancock, 2003) and allowing potentially greater statistical power (Yuan & Bentler, 2006). Currently, there appear to be no examinations of evolution education using these techniques.

Present Study

In summary, previous research on attitudes toward and knowledge of evolution have largely been either qualitative studies (Bishop & Anderson, 1990; Clores & Limjap, 2006) or manifest variable examinations of change (Grose & Simpson, 1982; Ingram & Nelson, 2006; Johnson & Peeples, 1987) in only a few constructs (e.g., knowledge of evolution, evolution misconceptions, attitudes toward evolution). The previous research has largely been conducted with inadequately validated measures and largely biology courses (Bishop & Anderson, 1990; Johnson & Peeples, 1987; Ingram & Nelson, 2006; Nehm & Schonfeld, 2008). An improvement upon past research examining evolution education is needed by employing latent variable examinations of change with a psychometrically validated measure across a variety of courses. Thus, the goal of present study was to employ a repeated measures multiple group confirmatory factor analysis (CFA) approach to evolution education research by examining change across a semester for a variety of courses using the EALS, a previously validated measure.

Because the main goal of the study was to examine change across the EALS constructs before and after a semester of instruction, students from three different undergraduate courses with varying amounts of evolution education were selected to be measured. An Introduction to U. S. Politics course offered by the political science department was selected as a control group for the current study, because the topic of evolution was not discussed at all within this course. An introductory course, The Principles of Cellular and Molecular Biology, was selected because evolution was often mentioned in the course and increasing understanding of evolution was emphasized. Third, an Evolutionary Psychology course was examined, because this course was centered on evolutionary theory and established specific goals of increasing evolutionary knowledge and acceptance. These three course samples will be referred to as the Political Science, Biology, and Evolutionary Psychology courses, respectively, for the remainder of this paper for clarity and consistency. Hypothesized change in each of the six EALS constructs are now discussed in turn below.

Hypotheses

Political Activity.

Political activity consists of an individual's self-reported degree to which they are politically active, aware, and have political views influence their daily life and decisions. Previous research has reported that one's civic knowledge positively predicts their political activity (Galson, 2001), but introductory political science courses showed little influence on political participation (Somit, Tanenhaus, Wilke, & Cooley, 1958). Because none of the above courses specifically dealt with civic knowledge, the construct Political Activity was not hypothesized to change after any of the three courses.

Religious Conservatism.

Religious conservatism is a complex construct largely characterized by how much an individual identifies themselves as politically conservative in general, how much an individual identifies themselves as politically conservative specifically on social, economic and foreign issues, how much religion impacts one's daily life and decisions, and the belief that life beings at conception (see Miller et al., 2006). The construct is also moderately characterized by how much one adheres to young-earth creationism and intelligent design ideas. None of the three selected course curricula specifically sought to change student's political or religious ideas. Thus, the construct Religious Conservatism was not hypothesized to change after any of the three courses.

Knowledge/Relevance.

The construct Knowledge/Relevance is the degree to which one both agrees with basic facts about genetics, evolutionary theory, and the scientific enterprise, and views evolutionary theory as relevant to various fields of study. As noted earlier, previous research has shown increases in acceptance and understanding of evolution both in biology (Bishop & Anderson, 1990; Grose & Simpson, 1982; Ingram & Nelson, 2006; Jensen & Finley, 1996; Johnson, & Peeples, 1987) and specific evolution (Wilson, 2005; O'Brien et al., 2009) courses. Thus, the construct Knowledge/Relevance was hypothesized not to change in the Political Science course, but increase for both the Biology course and the Evolutionary Psychology course.

Creationist Reasoning.

Creationist Reasoning is a construct characterized by adherence to intelligent design and young-earth creationist beliefs. Additionally, creationist reasoning is distinguished by a distrust of the scientific enterprise and both moral and social objections to evolutionary theory. The curriculum in the Evolutionary Psychology course was specifically designed to address the fallacies of young-earth creationist and intelligent design beliefs throughout the semester. Therefore, a decrease in Creationist Reasoning was hypothesized to be demonstrated among students in the Evolutionary Psychology course, but no change was expected for the Biology or Political Science courses.

Evolutionary Misconceptions.

Evolutionary Misconceptions are false beliefs about evolution, including both Lamarckian (e.g., a trait an organism acquires during its lifetime can be passed down to its offspring), and teleological ideas (e.g., species evolve in order to reach a finite goal). Unfortunately, past examinations of biology courses have revealed that students continue to adhere to evolutionary misconceptions even after a semester long biology course (Bishop & Anderson, 1990; Brumby, 1984; Jensen & Finley, 1996; Nehm & Reilly, 2007). Based on past research, the construct Evolutionary Misconceptions was not hypothesized to change for students in the Biology or Political Science course. However, this construct was hypothesized to change for the Evolutionary Psychology class, because specific curriculum was presented in the course to address the Lamarckian and teleological fallacies. Therefore, evolutionary misconceptions were expected to decrease among students in the Evolutionary Psychology course.

Exposure to Evolution.

The construct Exposure to Evolution consists of one's self-exposure to evolution-related media (e.g.,, web sites, videos, and publications) one's youth exposure to evolution (e.g., including visiting natural history museums), and how much evolution education one received prior to college. Because both the Biology course and Evolutionary Psychology course discussed evolution throughout the semester, Exposure to Evolution was hypothesized to increase for both of these courses. No change in Exposure to Evolution was hypothesized for the Political Science course because evolutionary theory was not addressed in the course.

Part II: Methods

Participants

In the current study, samples were collected from three different undergraduate courses taught at a large Midwestern university. The first sample was drawn from an introductory biology course covering the principles of cellular and molecular biology for biology majors or students planning to take additional biology courses. The sample consisted of 631 undergraduates representing 36 majors, including 246 (44.81%) men and 303 (55.19%) women. The sample was predominately Caucasian (77.45%) and largely consisted of first year college students (N = 342, 62.41%). Additionally, the average age was 19.18 years (SD = 2.74), and the most frequent response for both the participant's father's (N = 174, 31.99%) and mother's (N = 188, 34.24%) education was a four-year college degree. Lastly, the average rating for how rural the participant's home town was 3.20 (SD = 1.85) on a 7-point scale ranging from 1 (*not at all rural*) to 7 (*very rural*).

The second sample consisted of 366 students from the introduction to U. S. politics course with students representing 43 different majors. The sample consisted of 113 (44.84%) men and 139 women (55.16%). The sample was largely Caucasian (84.52%), and it consisted of mostly first year (N = 77, 30.92%) and second year (N = 91, 36.55%) college students. Additionally, the average age was 20.04 years (SD = 3.26), and the most frequent response for both the participant's father's (N = 66, 26.29%) and mother's (N = 100, 39.84%) education was a four- year college degree. Lastly, the average rating for how rural the participant's home town was 3.38 (SD = 2.05) on a 7-point scale.

The third sample consisted of 65 students from a course in evolutionary psychology representing 11 majors. The sample consisted of 37 (56.92%) men and 28 (43.08%) women, and it was composed of mostly Caucasians (92.96%) and fourth year college students (66.20%). Additionally, the average age was 21.30 years (*SD* = 1.26), and the most frequent response for both the participant's father's (*N* = 25, 38.57%) and mother's (*N* = 26, 39.44%) education was four-year college degree. Lastly, the average rating for how rural the participant's home town was 3.09 (*SD* = 1.82) on a 7-point scale.

Measures

Demographic variables.

A variety of demographic information was collected from each participant. First, participants were asked to report age, gender, ethnicity, father's education level (if known), mother's education level (if known), and year in college. Participants also self-reported the degrees to which their town was rural on a 7-point Likert scale ranging from 1 (*not at all*) to 7 (*very*). Additionally, the big five personality trait openness to experience was measured using the 10 item subscale from the Big Five Inventory (BFI; Benet-Martinez & John, 1998).

The Evolutionary Attitudes and Literacy Survey (EALS, Hawley et al., 2011).

The EALS consisted of 17 pages of web-presented items on which respondents rated the degrees to which they agreed or disagreed with 104 statements on a 7-point Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*) with the midpoint 4 (*neither agree nor disagree*). Example EALS items include: "All modern species of land vertebrates are descended from those original animals on the ark," "The theory of evolution has contributed to sexism," "The theory of evolution helps us understand animals," "Increased genetic variability makes a population more resistant to extinction," and "Natural selection is a random process".

The EALS measures 16 meaningful constructs: Political Activity, Religious Activity, Conservative Self Identity, Attitudes Toward Life, Intelligent Design Fallacies, Young-Earth Creationist Beliefs, Moral Objections, Social Objections, Distrust of the Scientific Enterprise, Relevance of Evolutionary Theory, Genetic Literacy, Evolutionary Knowledge, Knowledge about the Scientific Enterprise, Evolutionary Misconceptions, Self Exposure to Evolution, and Youth Exposure to Evolution.. These 16 constructs of the EALS can be further accounted for by 6 higher-order constructs representing Political Activity, Religious Conservatism, Creationist Reasoning, Knowledge/Relevance of Evolution, Evolutionary Misconceptions, and Exposure to Evolution.

Data Collection

Prior the start of the semester instructors from each of the courses were contacted and asked if they would be willing to allow their classes to participate in the current study. Upon agreement, each course instructor emailed all students during the first week of the semester and asked their students to complete an online survey outside of class time via an easy-to-access link that was posted on their course website. Thus, participants were measured prior to being exposed to course material. Participants were informed that the purpose of the study was to examine their attitudes about and knowledge of evolution, and they were asked to complete the survey after providing their consent. Participants were thanked upon completion and were provided with extra credit in their course for their participation. Participants were then contacted again 14 weeks later during the last week of course instruction, and they asked to complete the survey a second time as a follow-up in return for additional extra course credit. Participants were given one week from initial contact to complete the online survey during both assessments. Overall, the response rates were very high. Over 90% of enrolled students in each course completed at least one of the two waves of measurement. All participants were treated in accordance with the "Ethical principles of the psychologists and code of conduct" (American Psychological Association, 2002).

Missing Data

Overall, each group had only a moderate amount of missingness (25% for the Political Science course, 22% for the Biology course, and 2.5% for the Evolutionary Psychology course) totaling 22.5% across the entire dataset. The majority of the missing data were hypothesized to be due to attrition that was either missing completely at random (i.e., MCAR; attrition was not related to observed or unobserved variables), or missing at random (i.e., MAR; attrition was related to observed variables). Logistic regressions predicting Time 2 missingness were conducted for each group and can be found in Appendix A. Missing data were handled via full information maximum likelihood (FIML) estimation within Mplus version 6.0 (Muthén & Muthén, 2011). Age, gender, ethnicity, mother's education level, father's education level, year in college, and openness to experience were included as auxiliary variables for FIML estimation. Shafer and Graham (2002) report that FIML estimation can handle MAR missingness, is unbiased for moderate samples, and becomes more efficient as the sample size increases under normal conditions. Moreover, FIML estimation is far superior to traditional missing data procedures such as list-wise or pair-wise deletion (Enders, 2010).

Analyses

Measurement Models.

The collected data contained three groups measured across two time points (pre-course and post-course). First, an appropriate CFA null model for longitudinal data was specified by having each manifest variable load onto its own unique latent variable that is orthogonal to all other latent variables, equating the indicator loadings and means across time, and fixing the intercepts and residual variances to 0 (see Widaman & Thompson, 2003). Next, a CFA measurement model demonstrating the relationships between the measured (e.g., manifest) indicators and the latent constructs was specified with 12 latent constructs, including the six higher-order EALS constructs (e.g., Political Activity, Religious Conservatism, Creationist Reasoning, Knowledge/Relevance of Evolution, Evolutionary Misconceptions, and Exposure to Evolution) for the pre-course (i.e., Time 1) and post-course (i.e., Time 2) assessment. Political Activity was indicated by three parceled indicators of the six total items for the construct. Parceling has the added benefits of requiring fewer model parameter estimates, reduced sampling error, and decreasing the likelihood of correlated residuals between items (Little, Cunningham, Shahar, & Widaman, 2002). For Political Activity, parcels were created by utilizing the item-to-construct balancing technique (see Little et al., 2002) that involved pairing items with higher standardized factor loadings with items possessing lower standardized factor loadings.

Additionally, facet representative parcels were created by calculating the mean of all of the items within a particular subscale and using these means as indicators of the higher-order EALS constructs. For instance, the construct Religious Conservatism was indicated by the facet representative parcels religious activity, conservative self- identity, attitudes toward life, young-earth creationism, and relevance of evolution. Knowledge/Relevance was indicated relevance of evolution, genetic literacy, evolutionary knowledge, and philosophy of science. Creationist Reasoning was indicated by intelligent design fallacies, young-earth creationism, moral objections, social objections, and distrust of the scientific enterprise.

The construct Evolutionary Misconceptions was indicated by three item-to-construct balancing parcels from the evolutionary misconceptions subscale, and the construct Exposure to

Evolution was indicated by two self-exposure item-to-construct balancing parcels, and the facet representative parcel youth exposure to evolution. All six of the Time 2 constructs were indicated with the same pattern of items as those constructs measured prior to course instruction. Because the same items were measured across two time points, each Time 1 indicator had a correlated residual estimated for the corresponding Time 2 indicator. All models were identified by the effects-coding to avoid arbitrary assignment of one indicator loading to be fixed to 1.0 (i.e., marker variable identification), and to maintain the scaling metric of the indicators (see Little, Slegers, & Card, 2006) Completely standardized factor loadings for each parcel and across each course can be found in Table 1 for Time 1 and Table 2 for Time 2 assessments.

Model Invariance Testing.

Establishing invariance across time demonstrates the constructs are similar across both assessments (Widaman, Ferrer, & Conger, 2010), whereas group invariance demonstrates the constructs are similar across groups (Brown, 2006). Additional comparisons can be made once invariance is established. Both group and time invariance were tested simultaneously in the current study. First, configural invariance was established by specifying the same estimated parameter paths for each group. Second, weak invariance was established by equating the factor loadings (e.g., lamba matrix) across each group so that only one factor loading was estimated for each construct. Next, the item intercepts were equated across groups to establish strong invariance. Both the weak and strong invariance model constraints were deemed tenable if RMSEAs from each model were within the RMSEA confidence interval for the less constrained model. The change in CFI for each nested model was also examined because it is robust to model complexity and sample size (Cheung & Rensvold, 2002).

Once strong invariance was established, other tests could be competed. First, the homogeneity of variance and covariance matrices was tested across time and group. A chi-square difference test between the chi-square from the strong invariance model (e.g., free variance/covariance matrices between groups) and the chi-square from the homogeneity of variance and covariance matrix (e.g., equated variance and covariance matrix) was conducted to determine if model fit significantly worsened from the additional constraints. Additionally, phantom constructs were created to test the equality of latent correlations across time and groups (see Little, 1997; Rindskopf, 1984).

Finally, latent mean invariance tests were performed to examine potential mean differences across groups and time. First, the latent means for each construct were equated across groups to test for a group main effect (e.g., $A_{\text{Political Activity, Poli Sci}} = A_{\text{Political Activity, Bio}} = A_{\text{Political Activity, Evo Psyc}}$). Next, latent mean invariance across time for each construct was tested by equating the latent mean of each construct for Time 1 and Time 2 observations (e.g., $A_{\text{Time 1Political Activity}} = A_{\text{Time 2 Political Activity}}$). All constrained means models were compared to the strong invariance model via a chi-square difference test to determine if equality constraints were tenable.

Part 3: Results

Confirmatory Factor Analyses

Measurement Model.

Table 1 and Table 2 display all items along with their corresponding parcels and standardized factor loadings. Overall, the measurement model CFA demonstrated acceptable fit, χ^2 (2178, N = 1062) = 3858.48, *p* <.0001, comparative fit index (CFI) = .94, Tucker-Lewis fit index (TLI) = .93, RMSEA = $.047_{(.044,.049)}$, SRMR = .056. Modification indices were examined in order to ensure the CFA produced the best fitting model. These indices were relatively low with a $\Delta\chi^2 < 10\%$ of the overall chi-square, and lacked theoretical support. Therefore, the current measurement model was maintained.

Group and Time Invariance.

Table 4 displays the model fit statistics from the simultaneous test of group and time invariance. The loadings across the three courses and two time points were equated for each construct for the weak invariant model. Weak factorial invariance was met with no significant change in model fit with the RMSEA from the weak factorial model fit within the 90% RMSEA confidence interval for the configural invariant model and the change in CFI was less than .01 (Cheung & Rensvold, 2002) and the change in TLI was less than .01. Similarly, equality of the indicator intercepts was met with the strong invariant model with the RMSEA, CFI, and TLI meeting the same criteria listed above for the weak invariant model.

Strong invariance across both time and courses allowed for additional comparisons to be made. Table 5 displays the tests of homogeneity of variance and covariance matrices. The test of homogeneity of variance and covariance matrices was significant, $\Delta\chi^2$ (162) = 326.12, $p < .0001$, indicating that the variances and covariances between constructs did differ across groups and/or time. Further examination revealed significant differences existed with both group, $\Delta\chi^2$ (156) = 305.58, $p < .0001$, and time, $\Delta\chi^2$ (19) = 42.07, $p < .01$. Because variance and covariance constraints across group and time were not tenable, equality of variances tests were conducted determine where significant differences existed. For time, the equality of variances constraint was tenable, $\Delta\chi^2$ (18) = 30.64, $p > .01$. Thus, each construct did not significant differ in variances across time.

Conversely, the equality of variances constraint across groups was not tenable, $\Delta\chi^2$ (24) = 49.21, $p < .01$, indicating that differences in latent variances existed between groups. Additional tests within groups revealed the equality constraint was not tenable due to significant differences in Time 1 Political Activity, $\Delta\chi^2$ (2) = 17.25, $p <$ .01, and Time 2 Creationist Reasoning, $\Delta\chi^2$ (2) = 17.25, $p <$ .01. Specifically, Time 1 Political Activity variance for the Political Science course ($\Psi_{PoliSci}$ = 1.92) was significantly larger than Biology and Evolutionary Psychology course (Ψ_{Bio} = Ψ_{EvoPsy} = 1.41). Time 2 Creationist Reasoning variance for the Evolutionary Psychology course (Ψ_{EvoPsy} = 0.27) was significantly lower than Political Science and Biology ($\Psi_{PoliSci}$ = Ψ_{Bio} = 0.705).

Because significant differences in the latent variances can make comparisons between each course's latent covariances difficult, phantom variables were used to standardize the latent covariances and convert them to latent correlations that can be directly compared across groups. The test of equality of correlations was not significant, $\Delta\chi^2$ (75) = 98.43, $p >$ .01, indicating that all constructs across each group had a similar pattern and magnitude of correlations.

Testing the Hypotheses

After group and time invariance were established the hypothesized differences could be examined by testing equality of the latent means. Table 5 includes the unconstrained latent means and standard deviations for each course and Table 6 includes the omnibus test of latent mean invariance, as well as additional follow-up tests exploring mean differences within group and time. The omnibus test of latent mean invariance was significant, $\Delta\chi^2$ (30) = 205.46, $p <$ .0001, as well as the main effect for Course, $\Delta\chi^2$ (24) = 24, $p <$ .0001, and the main effect of time, $\Delta\chi^2$ (18) = 53.69, $p <$ .0001. Because both main effects were significant, simple main effects for each construct were examined within time. If the simple main effect of a construct within time was significant (i.e., significant differences in latent means existed between Time 1 and Time 2 for each construct), then the effect was examined within each group to determine where the differences existed. The results for the six EALS constructs are described below.

Political Activity.

The test of latent mean invariance across time for Political Activity was not significant, $\Delta\chi^2$ (3) = 3.18, p = .36. Political Activity did not change from pre-course to post-course assessment for the Biology, Political Science, or Evolutionary Psychology course.

Religious Conservatism.

The test of latent mean invariance across Religious Conservatism was not significant, $\Delta\chi^2$ (3) = 4.64, p = .20. Religious Conservatism did not change from pre-course to post-course assessment for the Biology, Political Science, or Evolutionary Psychology course.

Knowledge/Relevance.

The test of latent mean invariance across Knowledge/Relevance of Evolution was significant, $\Delta\chi^2$ (3) = 23.87, $p < .001$. Thus, each course was examined for possible mean differences across time. Knowledge/Relevance of Evolution did not significantly differ across time in the Biology course, $\Delta\chi^2$ (1) = 3.55, p = .07, but significant differences did exist for the Political Science course ($A_{\text{Time 1}}$ = 4.88, SE = 0.05; $A_{\text{Time 2}}$ = 4.98, SE = 0.05), $\Delta\chi^2$ (1) = 7.81, $p < .01$, and the Evolutionary Psychology course ($A_{\text{Time 1}}$ = 5.80, SE = 0.10; $A_{\text{Time 2}}$ = 6.16, SE = 0.10), $\Delta\chi^2$ (1) = 12.71, $p < .001$. The effect size for the Political Science course was small (d = .13), and moderate (d = .52) for the Evolutionary Psychology course.

Creationist Reasoning.

The test for latent mean invariance across Creationist Reasoning was significant, $\Delta\chi^2$ (3) = 31.26, $p < .001$. Thus, each course was examined for possible mean differences across time. Creationist Reasoning did not significantly differ across time for both the Biology, $\Delta\chi^2$ (1) =

0.03, $p = .87$, and Political Science courses, $\Delta\chi^2$ (1) = .01, $p = .94$. Conversely, Creationist Reasoning did significantly differ across time for the Evolutionary Psychology course, with pre-course Creationist reasoning ($A_{Time\ 1} = 1.88$, $SE = 0.10$) significantly greater than post-course Creationist Reasoning ($A_{Time\ 2} = 1.50$, $SE = 0.08$), $\Delta\chi^2$ (1) = 31.23, $p < .001$. There was a moderate effect size ($d = -0.64$) for this significant difference.

Evolutionary Misconceptions.

The test for latent mean invariance across Evolutionary Misconceptions was significant, $\Delta\chi^2$ (3) = 12.89, $p < .01$. Thus, each course was examined for possible mean differences across time. Evolutionary Misconceptions did not significantly differ across time for both the Biology, $\Delta\chi^2$ (1) = 0.29, $p = .59$, and Political Science courses, $\Delta\chi^2$ (1) = 0.41, $p = .52$. Conversely, Evolutionary Misconceptions did significantly differ across time for the Evolutionary Psychology course. Post-course Evolutionary Misconceptions, ($A_{Time2} = 2.94$, $SE = 0.14$) were significantly lower than pre-course Evolutionary Misconceptions ($A_{Time\ 1} = 3.39$, $SE = 0.13$, $\Delta\chi^2$ (1) = 12.19, $p < .001$. There was a moderate effect size ($d = -.47$) for this significant difference.

Exposure to Evolution

The test of latent mean invariance across Exposure to Evolution was not significant, $\Delta\chi^2$ (3) = 5.01, $p = .17$. Exposure to Evolution did not change from pre-course to post-course assessment for the Biology, Political Science, or Evolutionary Psychology course.

Part 4: Discussion

Currently, a significant portion of the American public, including both teachers and students, are neutral to evolutionary theory and education at best, or fully opposed to this fundamental theory in science education at worst. The present study sought to conduct a modern quantitative examination of the effects of semester long college courses varying in amounts of evolution education to determine if the curricula were effective in changing some of the complex constructs influencing attitudes toward and knowledge of evolution. Several important results were discovered when testing the hypotheses and are now discussed in turn.

First, as hypothesized, there was no significant change in students' Political Activity or Religious Conservatism prior to or following a semester long course in Biology, Political Science, or Evolutionary Psychology. None of these course contained curriculum specifically designed to increase a student's political participation, conservative beliefs, or religious activity, and, as such, no change was observed. However, the Political Science course demonstrated significantly more variability in Political Activity, indicating that Biology and Evolutionary Psychology students were more homogenous in their reported influence of politics in their daily life.

Significant change in Knowledge/Relevance of evolution was observed for the Evolutionary Psychology course, but, surprisingly, no change was observed in the Biology course. A few possible explanations may exist for these differing results. First, the Evolutionary Psychology course consisted of instruction devoted to understanding the historical background and fundamentals of evolutionary theory, whereas less time may have been devoted to evolution education in the biology course. Unfortunately, detailed examinations of the breadth and depth of evolution education in these courses was not conducted and is an important next step for future research. Additionally, student enrollment in the Biology course was nearly ten times larger than the Evolutionary Psychology course, but previous research suggests that the many other factors outside of class size influence curricular effectiveness (Ehrenberg, Brewer, Gamoran, & Willms, 2001). One important implication of these results is that significant gains in student knowledge and relevance of evolutionary theory may be possible if educators devote instructional time to a comprehensive examination of evolutionary theory (see also O'Brien et al., 2009, Wilson, 2005). Interestingly, evolutionary knowledge increased for the Political Science course, but the small effect size indicates that the increase is not of much practical significance.

Another notable result was the significant decrease in Creationist Reasoning and Evolutionary Misconceptions for the Evolutionary Psychology course. Previous research has indicated that instructors must go beyond lecturing and employ active teaching styles to increase students' evolutionary knowledge (Alters & Nelson, 2002; Nehm & Reilly, 2007). The present results may indicate that these past findings can be extended to reductions in creationist reasoning and evolutionary misconceptions. Student activities present in the Evolutionary Psychology course, such as critical examinations of evolutionary fallacies, may be some of the necessary instructional methods outside of traditional lectures needed to decrease false views of evolution. Moreover, Evolutionary Psychology students had significantly less variability in their Time 2 Creationist Reasoning when compared to Political Science and Biology students. Thus, these additional curricular activities not only reduced, but also homogenized students' disagreement with survey items pertaining to young-earth creationist and intelligent design fallacies. These results may certainly be encouraging to many researchers (e.g., O'Brien et al., 2009; Wilson, 2005) diligently working toward improving evolution education.

No change in Evolutionary Misconceptions for the Biology course was hypothesized, and was supported by the current results. Biology students reported that they slightly disagreed with the items evolutionary misconceptions at the beginning of the semester on average, but unlike students in the Evolutionary Psychology course, the Biology students did not report significantly more disagreement with these statements at the end of the semester. This finding is certainly important for educators, as it again suggests that one's knowledge of basic scientific principles does not eliminate their intuitive and incorrect misunderstandings about evolution. In fact, the salience of misconceptions in science is not unique to the biological sciences. McCloskey (1983) found similar results in physics. The majority of students still held onto their false intuitions about basic physical concepts even after the students had completed a course on introductory physics. Similar to McCloskey's (1983) findings with physics, participants may have encountered their misconceptions about evolution prior to specifically learning about evolution and simply adapted the new material to fit their existing framework. These evolutionary misconceptions were even shown to persist among science graduate students (Gregory & Ellis, 2009).

The hypotheses for Exposure to Evolution were not supported because no significant increase was observed in the Biology or Evolutionary Psychology course. Differences across time for students' Exposure to Evolution may not have been present because the construct was partly indicated by the amount of exposure an individual had to evolutionary theory prior to college. These items cannot change after enrolling in college, and any observed change in the construct Exposure to Evolution had to be due to increases in an individual's self-exposure to evolution. In addition, the items measuring self-exposure to evolution pertained to evolution materials, such as websites, videos, magazines, and documentaries, that are likely not a mandatory part of a traditional lecture-based science course. Courses that make these outside materials available to students may be more likely to see changes in self-exposure to evolution.

Limitations and Future Research

Several limitations and directions for future research exist. For example, only students at a large Midwestern university were examined and additional comparisons of other university samples across the nation are needed to provide a clearer representation of the effectiveness of evolution education across America. Examinations of high school science teacher's attitudes toward evolution have been conducted (Osif, 1997; Nehm et al., 2009), but additional research is needed on the attitudes of college educators (see Rutledge & Mitchell, 2002) and how these attitudes correspond to the quantity and quality of evolutionary content in their courses. Also, final course grades were not examined in the present study, but are certainly of interest. Future researchers should continue to investigate the positive relationship between attitudes toward evolution and final course grades (Ingram & Nelson, 2006) with longitudinal designs that can test the potential causal link between an individual's attitude toward a subject and their resulting grade. Finally, the construct Exposure to Evolution may have been inappropriately defined by including measures of youth exposure to evolution and exposure to evolution materials that, regretfully, may not be present in some curricula. Future measures of exposure to evolution should include more items specifically addressing evolution materials within the course to determine if students are receiving additional exposure to evolution than they had encountered prior to the course.

In conclusion, a significant and notable increase in evolution knowledge/relevance, as well as decrease in creationist reasoning and evolutionary misconceptions was observed for the evolutionary psychology course. In contrast, no significant change in evolution knowledge/relevance was observed for the biology course. The results from the present study offer some encouragement to evolution educators, provide a more insight into the effects of college courses on attitudes toward and knowledge of evolution, and again demonstrates the need for additional improvements in evolution education. Once again, this study implies that it would be false to assume that students fully understand evolutionary theory upon completing a course in biology. Science instructors aiming to increase student's evolutionary knowledge must deliberately go beyond traditional lectures, directly addresses frequent misconceptions, and frequently demonstrates the relevance of evolution in order to change a student's knowledge and attitude towards this unifying theory.

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Table 1

Time 1 Model Parcels and Completely Standardized Factor Loadings

Construct	Parcel	Completely Standardized Factor Loading		
		Political Science	Biology	Evolutionary Psychology
Political Activity				
	Political Activity P1	.888	.836	.810
	Political Activity P2	.897	.934	.897
	Political Activity P3	.919	.891	.939
Religious Conservatism				
	Religious Activity	.825	.817	.649
	Conservative Self-Identity	.565	.510	.526
	Attitudes Toward Life	.628	.675	.701
	Intelligent Design Fallacies	.342	.443	.698
	Young-Earth Creationism	.480	.545	.536
	Relevance	-.213	-.320	-.319
Knowledge/Relevance				
	Relevance	.643	.568	.533
	Genetic Literacy	.897	.873	.758
	Evolutionary Knowledge	.765	.798	.772
	Knowledge of the Scientific Enterprise	.699	.654	.760
Creationist Reasoning				
	Intelligent Design Fallacies	.688	.592	.317
	Young-Earth Creationism	.526	.461	.448
	Moral Objections	.681	.723	.464
	Social Objections	.724	.801	.635
	Distrust for the Scientific Enterprise	.840	.867	.921
Evolutionary Misconceptions				
	Evolutionary Misconceptions P1	.545	.666	.743
	Evolutionary Misconceptions P2	.781	.642	.626
	Evolutionary Misconceptions P3	.642	.500	.572
Exposure to Evolution				
	Self-Exposure P1	.880	.928	.861
	Self-Exposure P2	.847	.794	.779
	Youth Exposure to Evolution	.602	.603	.788

Table 2

Time 2 Model Parcels and Completely Standardized Factor Loadings

Construct	Parcel	Completely Standardized Factor Loading		
		Political Science	Biology	Evolutionary Psychology
Political Activity				
	Political Activity P1	.885	.874	.862
	Political Activity P2	.927	.944	.930
	Political Activity P3	.947	.910	.873
Religious Conservatism				
	Religious Activity	.841	.829	.655
	Conservative Self-Identity	.564	.515	.519
	Attitudes Toward Life	.667	.641	.691
	Intelligent Design Fallacies	.265	.440	.482
	Young-Earth Creationism	.299	.536	.076
	Relevance	-.179	-.315	-.201
Knowledge/Relevance				
	Relevance	.723	.566	.722
	Genetic Literacy	.846	.899	.671
	Evolutionary Knowledge	.878	.816	.917
	Knowledge of the Scientific Enterprise	.639	.642	.818
Creationist Reasoning				
	Intelligent Design Fallacies	.766	.591	.722
	Young-Earth Creationism	.724	.482	.829
	Moral Objections	.832	.819	.346
	Social Objections	.750	.841	.404
	Distrust for the Scientific Enterprise	.843	.901	.745
Evolutionary Misconceptions				
	Evolutionary Misconceptions P1	.620	.710	.946
	Evolutionary Misconceptions P2	.735	.647	.621
	Evolutionary Misconceptions P3	.625	.611	.615
Exposure to Evolution				
	Self-Exposure P1	.879	.951	.925
	Self-Exposure P2	.884	.812	.714
	Youth Exposure to Evolution	.701	.616	.694

Table 3

Latent Correlations among Time 1 and Time 2 EALS Constructs

Construct	1	2	3	4	5	6	7	8	9	10	11	12
1. T1 Political Activity	1.00											
2.T1 Religious Conservatism	-0.04*	1.00										
3.T1 Knowledge/Relevance	0.16	-0.53	1.00									
4. T1 Creationist Reasoning	-0.09	0.70	-0.73	1.00								
5. T1 Evolutionary Misconceptions	-0.01*	0.06*	-0.10	0.21	1.00							
6. T1Exposure to Evolution	0.31	-0.37	0.43	-0.38	-0.07	1.00						
7. T2 Political Activity	0.72	-0.05*	0.20	-0.16	-0.02*	0.17	1.00					
8.T2 Religious Conservatism	-0.10	0.93	-0.56	0.71	0.07*	-0.40	-0.04*	1.00				
9.T2 Knowledge/Relevance	0.07*	-0.53	0.90	-0.71	-0.13	0.40	0.16	-0.53	1.00			
10. T2 Creationist Reasoning	-0.03*	0.69	-0.69	0.87	0.12*	-0.37	-0.09	0.70	-0.73	1.00		
11. T2 Evolutionary Misconceptions	-0.08*	0.03*	-0.10*	0.19	0.28	-0.05*	-0.01*	0.06*	-0.10	0.21	1.00	
12. T2 Exposure to Evolution	0.39	-0.35	0.44	-0.38	-0.23	0.72	0.31	-0.37	0.43	-0.38	-0.07	1.00

Note. T1 = Time 1, T2 = Time 2, * p >.05. Values from Equality of Correlations (Phantom Constructs) Model.

Table 4

Fit Indices for Model Invariance Testing

Model	χ^2	*df*	*p*	$\Delta\chi^2$	Δ *df*	*p*	RMSEA	RMSEA 90% CI	NNFI	CFI	Constraint Tenable
Null Model	54323.13	2709	<.001	---	---	---	---	--- ---	---	---	---
Configural Invariance[1]	3858.48	2178	<.001	---	---	---	0.047	0.044-0.049	0.925	0.937	---
Weak Invariance[1]	4082.19	2268	<.001	---	---	---	0.048	0.045-0.050	0.922	0.932	Yes
Strong Invariance[1]	4391.27	2243	<.001	---	---	---	0.050	0.047-0.052	0.915	0.923	Yes
Homogeneity of Variances/Covariances[2]	4717.39	2505	<.001	326.118	162	<.001	---	--- ---	---	---	No
Group	4696.85	2499	<.001	305.579	156	<.001					No
Time	4433.34	2363	<.001	42.066	19	<.01					No
Homogeneity of Variances[2]	4454.43	2373	<.001	63.154	30	<.001	---	--- ---	---	---	No
Equality of Correlations (Phantom Constructs)[2]	4489.71	2418	<.001	98.432	75	.0362	---	--- ---	---	---	Yes
Latent Mean Invariance[2]	4596.73	2373	<.001	205.46	30	<.001	---	--- ---	---	---	No

[1] Evaluated with RMSEA Model Test
[2] Evaluated with χ^2 Difference Test
Note. Each nested model contains its constraints, plus the constraints of all previous, tenable models. Group and Time invariance was tested simultaneously.

Table 5

Test of the Variances

Model	χ^2	*df*	*p*	$\Delta \chi^2$	Δ *df*	*p*	Constraint Tenable
Intercept Invariance (Baseline model)	4391.27	2243	<.001	---	---	---	---
Equality of Variances	4454.427	2373	<.0001	63.154	30	<.001	No
Group	4440.480	2367	<.0001	49.207	24	0.002	No
T1 Political Activity	4399.484	2345	<.0001	8.211	2	0.016	No
T1 Religious Conservatism	4395.764	2345	<.0001	4.491	2	0.106	Yes
T1 Knowledge/Relevance	4391.597	2345	<.0001	0.324	2	0.850	Yes
T1 Creationist Reasoning	4394.416	2345	<.0001	3.143	2	0.208	Yes
T1 Evolutionary Misconceptions	4394.304	2345	<.0001	3.031	2	0.220	Yes
T1Exposure to Evolution	4391.291	2345	<.0001	0.018	2	0.991	Yes
T2 Political Activity	4397.781	2345	<.0001	6.508	2	0.039	Yes
T2 Religious Conservatism	4394.076	2345	<.0001	2.803	2	0.246	Yes
T2 Knowledge/Relevance	4392.677	2345	<.0001	1.404	2	0.496	Yes
T2 Creationist Reasoning	4408.519	2345	<.0001	17.246	2	<.001	No
T2 Evolutionary Misconceptions	4399.061	2345	<.0001	7.788	2	0.020	Yes
T2 Exposure to Evolution	4391.504	2345	<.0001	0.231	2	0.891	Yes
Time	4421.909	2361	<.0001	30.636	18	0.0317	Yes
Political Science	4401.205	2349	<.0001	9.932	6	0.1275	Yes
Biology	4402.232	2349	<.0001	10.959	6	0.0897	Yes
Evolutionary Psychology	4400.981	2349	<.0001	9.708	6	0.1375	Yes

Note. T1 = Time 1, T2 = Time 2.

Table 6

Estimated Latent Means

	Political Science		Biology		Evolutionary Psychology	
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Political Activity	3.304 (1.587)	3.272 (1.587)	2.895 (1.306)	2.979 (1.356)	2.991 (1.201)	2.991 (1.129)
Religious Conservatism	2.284 (1.224)	2.274 (1.186)	2.267 (1.407)	2.267 (1.407)	1.657 (0.766)	1.598 (0.750)
Knowledge/Relevance	4.883 (1.014)	4.984 (1.052)	5.260 (1.105)	5.201 (1.181)	5.802 (0.798)	6.161 (0.774)
Creationist Reasoning	2.501 (1.244)	2.498 (1.301)	2.327 (1.457)	2.332 (1.507)	1.881 (0.790)	1.495 (0.661)
Evolutionary Misconceptions	3.891 (0.957)	3.933 (0.995)	3.938 (0.955)	3.962 (1.105)	3.387 (1.040)	2.942 (1.145)
Exposure to Evolution	2.243 (0.765)	2.252 (0.784)	2.373 (0.728)	2.394 (0.779)	2.560 (0.677)	2.702 (0.645)

Note. Means (Standard Deviations)

Table 7

Test of the Latent Means

Model	χ^2	*df*	*p*	$\Delta\chi^2$	Δ *df*	*p*	Constraint Tenable	Effect Size[1]
Intercept Invariance (Baseline model)	4391.27	2243	<.001	---	---	---	---	---
Latent Mean Invariance	4596.73	2373	<.001	205.46	30	<.001	No	---
Group	4586.812	2367		195.539	24		No	---
Time	4444.967	2361	<.0001	53.694	18	<.001	No	---
Political Activity	4394.456	2346	<.0001	3.183	3	0.364	Yes	---
Religious Conservatism	4395.917	2346	<.0001	4.644	3	0.200	Yes	---
Knowledge/Relevance	4415.143	2346	<.0001	23.87	3	<.001	No	---
Political Science	4399.081	2344	<.0001	7.808	1	<.01	No	0.13
Biology	4394.628	2344	<.0001	3.355	1	0.067	Yes	---
Evolutionary Psychology	4403.98	2344	<.0001	12.707	1	<.001	No	0.52
Creationist Reasoning	4422.537	2346	<.0001	31.264	3	<.001	No	---
Political Science	4391.278	2344	<.0001	0.005	1	0.944	Yes	---
Biology	4391.299	2344	<.0001	0.026	1	0.872	Yes	---
Evolutionary Psychology	4422.505	2344	<.0001	31.232	1	<.001	No	-0.64
Evolutionary Misconceptions	4404.163	2346	<.0001	12.89	3	<.001	No	---
Political Science	4391.685	2344	<.0001	0.412	1	0.521	Yes	---
Biology	4391.563	2344	<.0001	0.29	1	0.590	Yes	---
Evolutionary Psychology	4403.461	2344	<.0001	12.188	1	<.001	No	-0.47
Exposure to Evolution	4396.278	2346	<.0001	5.005	3	0.171	Yes	---

[1] Effect size is latent *d*, where $d = (\alpha_{2j} - \alpha_{1j}) / \sqrt{\psi_{pooled}}$

Appendix A

Logistic Regressions of Time 2 Missingness

Overall, each group had only a moderate amount of missingness (25% for the Political Science course, 22% for the Biology course, and 2.5% for the Evolutionary Psychology course) totaling 22.5% across the entire dataset. Prior to start of the semester participants in each of the three courses completed the EALS as well as demographic variables. At the end of the semester participants again completed the EALS with 69 %, 68%, and 90% completing both assessments for the political science, biology, and evolutionary psychology course, respectively. A dummy coded variable with 0 = “Completed Time 2” and 1 = “Missing Time 2” was created for each participant and was predicted by the demographic variables age, gender, mother’s education level, father’s education level, cumulative grade point average (GPA), ACT score, and the big five personality variable openness to experience.

Table A1 displays the results of the logistic regression predicting time 2 missingness for the political science course. The full model with all demographic predictors was significantly better at predicting time 2 missingness than a constant-only model, χ^2 (8, N = 366) = 21.837, p = .005. Both GPA, β = -0.722, p = .007, and Rural, β = -0.151, p = .043, were significant negative predictors of time 2 missingness. Thus, students with lower cumulative GPAs and less rural hometowns (i.e. more urban) were more likely to not complete the time 2 assessment. Additionally, openness to experience was a significant positive predictor of time 2 missingness, β = 0.721, p = .009, indicating that students with more openness to experience were more likely to not complete the time 2 assessment.

Table A2 displays the results of the logistic regression predicting time 2 missingness for the biology course. The full model with all demographic predictors was significantly better at prediction time 2 missingness than a constant-only model, χ^2 (8, N = 631) = 39.891, $p <$ .001. Both GPA, β = -0.606, p = .001, and ACT, β = -0.134, p < .001, were significant negative predictors of time 2 missingness. Thus, students with lower cumulative GPAs and lower ACT scores were more likely to not complete the time 2 assessment. Table A3 displays the results of the logistic regression predicting time 2 missingness for the evolutionary psychology course. The full model with predictors did not significantly differ from a constant-only model, χ^2 (8, N = 65) = 7.254, p = .510. There were no significant predictors in the model.

Table A1

Logistic Regression Predicting Time 2 Missing Data for the Political Science Course

Variable	*B*	*p*	Odds Ratio	95 % Confidence Interval for Odds Ratio	
				Lower	Upper
Age	-0.091	.210	0.913	0.792	1.029
Gender	-0.105	.713	0.900	0.514	1.441
Mom Edu	-0.074	.541	0.928	0.731	1.134
Dad Edu	0.111	.252	1.118	0.924	1.311
GPA	-0.722*	.007	0.486	0.287	0.755
ACT	-0.059	.209	0.942	0.859	1.019
Rural	-0.151*	.043	0.860	0.743	0.972
Openness	0.721*	.009	2.056	1.198	3.234
(Constant)	2.755	.188			

Note. Time 2 missing is coded 0 for *Not Missing* and 1 for *Missing*. Gender is coded 1 for Men and 2 for Women. Mom Edu and Dad Edu = a participant's mother's and father's highest education level, GPA = cumulative grade point average, ACT = score on ACT, Rural = how rural a participant's self reported their home town and was scored from 1 *not rural at all* to 7 *very rural*, and Openness = mean score on 10 item measure openness to experience from the Big Five Inventory (Benet-Martinez & John, 1998).

$\chi^2(8, N = 366) = 21.837$, $p = .005$

*$p < .05$.

Table A2

Logistic Regression Predicting Time 2 Missing Data for the Biology Course

Variable	*B*	*p*	Odds Ratio	95 % Confidence Interval for Odds Ratio	
				Lower	Upper
Age	-0.066	0.218	0.937	0.844	1.022
Gender	-0.105	0.585	0.900	0.617	1.236
Mom Edu	-0.013	0.855	0.987	0.857	1.111
Dad Edu	0.047	0.472	1.048	0.922	1.168
GPA	-0.606*	0.001	0.546	0.377	0.744
ACT	-0.134*	0.000	0.875	0.827	0.918
Rural	0.092	0.098	1.097	0.983	1.202
Openness	0.156	0.404	1.169	0.810	1.589
(Constant)	-5.218	0.001			

Note. Time 2 missing is coded 0 for *Not Missing* and 1 for *Missing*. Gender is coded 1 for Men and 2 for Women. Mom Edu and Dad Edu = a participant's mother's and father's highest education level, GPA = cumulative grade point average, ACT = score on ACT, Rural = how rural a participant's self reported their home town and was scored from 1 *not rural at all* to 7 *very rural*, and Openness = mean score on 10 item measure openness to experience from the Big Five Inventory (Benet-Martinez & John, 1998).

χ^2 (8, N = 631) = 39.891, $p <$ .001.

*p < .05.

Table A3

Logistic Regression Predicting Time 2 Missing Data for the Evolutionary Psychology Course

Variable	*B*	*p*	Odds Ratio	95 % Confidence Interval for Odds Ratio	
				Lower	Upper
Age	-0.994	.120	0.370	0.131	1.050
Gender	0.767	.062	2.154	0.099	46.779
Mom Edu	-0.260	.625	0.771	0.231	2.572
Dad Edu	0.245	.673	1.278	0.492	3.321
GPA	-0.319	.615	0.727	0.389	1.359
ACT	0.009	.318	1.009	0.585	1.741
Rural	1.739	.973	5.691	0.119	272.426
Openness	-2.010	.378	0.134	0.003	5.987
(Constant)	25.820	.120			

Note. Time 2 missing is coded 0 for *Not Missing* and 1 for *Missing*. Gender is coded 1 for Men and 2 for Women. Mom Edu and Dad Edu = a participant's mother's and father's highest education level, GPA = cumulative grade point average, ACT = score on ACT, Rural = how rural a participant's self reported their home town and was scored from 1 *not rural at all* to 7 *very rural*, and Openness = mean score on 10 item measure openness to experience from the Big Five Inventory (Benet-Martinez & John, 1998).

χ^2 (8, N = 65) = 7.254, p = .510.

**p* < .05.